Blind millimeter line emitter search using ALMA data toward gravitational lensing clusters (Yamaguchi et al. 2017, ApJ in press; arXiv: 1707.05547)

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Abstract

We present the results of a blind millimeter line emitter search using ALMA Band 6 data with a single frequency tuning toward four gravitational lensing clusters. We construct 3D S/N cubes with 60 MHz and 100 MHz binning, and search for millimeter line emitters. We do not detect any line emitters with a peak S/N > 5, although we do find emitter candidate with a peak S/N ~ 4.5. These results provide upper limits to the CO(3-2), CO(4-3), CO(5-4), and [CII] luminosity functions at z ≃ 0.3, 0.7, 1.2, and 6, respectively. Because of the magnification effect of gravitational lensing clusters, the new data provide the first constraints on the CO and [CII] luminosity functions at unprecedentedly low luminosity levels. Although the constraints to date are not stringent yet, we find that the evolution of the CO and [CII] luminosity functions are broadly consistent with the predictions of semi-analytical models. This study demonstrates that the wide observations with a single frequency tuning toward gravitational lensing clusters are promising for constraining the CO and [CII] luminosity functions.

Introduction

Constraining the cosmic star formation density and molecular gas mass density via blind line emitter search is important to understand the star formation history in the universe. However, observational costs (e.g., total observation time) of blind line emitter search based on ALMA spectral scan (i.e., frequency range > several × 10 GHz) are large.

In this study, we present a blind line emitter search using ALMA Band 6 observations toward 4 gravitational lensing clusters with only one frequency tuning (i.e., frequency range ~ 8 GHz) to constrain line luminosity functions.

ALMA data

Our ALMA observations + ALMA archival data

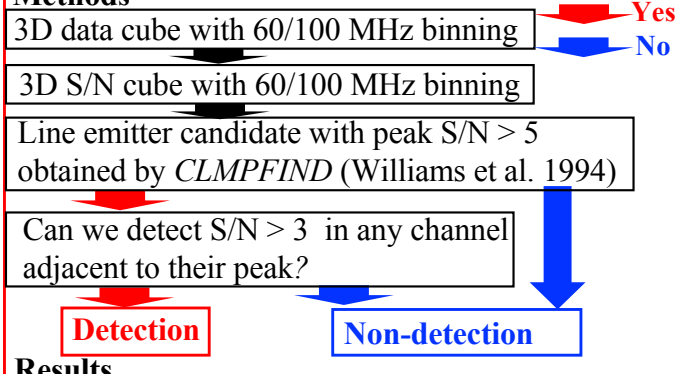
- RXJ1347, Abell S0592; Project ID: 2013.1.00724.S, PI: H. Ezawa
  - Our ALMA Band 6 observations
- MACS J0416, Abell 2744; Project ID: 2013.1.00999.S, PI: F. Bauer
  - ALMA Band 6 archival data

Target	$z_{cluster}$	A [arcmin^2]	ν_{obs} [GHz]	$\sigma_{cont.}$ [μJy beam^{-1}]	Synthesized beam	$\Delta\nu$ [GHz]	$\sigma_{60\ MHz}$ [mJy beam^{-1}]	$\sigma_{100\ MHz}$ [mJy beam^{-1}]	$t_{obs.}$ [hrs.]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
RXJ1347.5−1145	0.451	4.75	265	155	1.″3 × 0.″72 (78°)	255–259 271–275	1.4	1.2	2.26
Abell S0592	0.222	3.63	265	150	1.″2 × 0.″75 (87°)	255–259 271–275	1.2	1.0	1.91
MACS J0416.1−2403	0.397	4.45	263	73	1.″5 × 0.″85 (−84°)	254–257 269–272	0.73	0.56	8.50
Abell 2744	0.308	4.26	263	91	1.″5 × 1.″2 (88°)	254–257 269–272	0.95	0.77	7.89

NOTE—(1) Cluster name. (2) Redshifts of lensing clusters. (3) Observed area. (4) Central frequencies of observations. (5) Typical sensitivities of continuum maps. (6) Synthesized beam size of continuum map. Position angles of synthesized beams are given in parenthesis. (7) Observed frequency setting. (8) Typical sensitivities of 3D data cube with 60 MHz binning. (9) Typical sensitivities of 3D data cube with 100 MHz binning. (10) Total observation time.

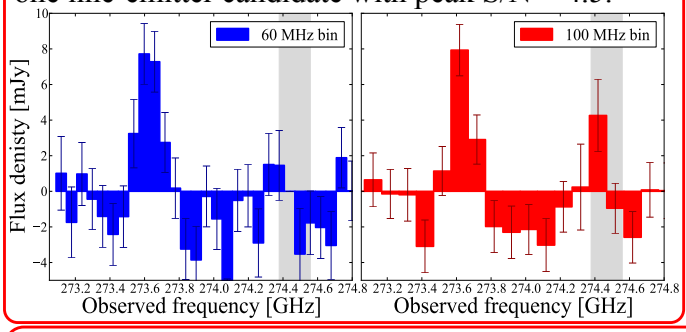
Methods & Results

Methods

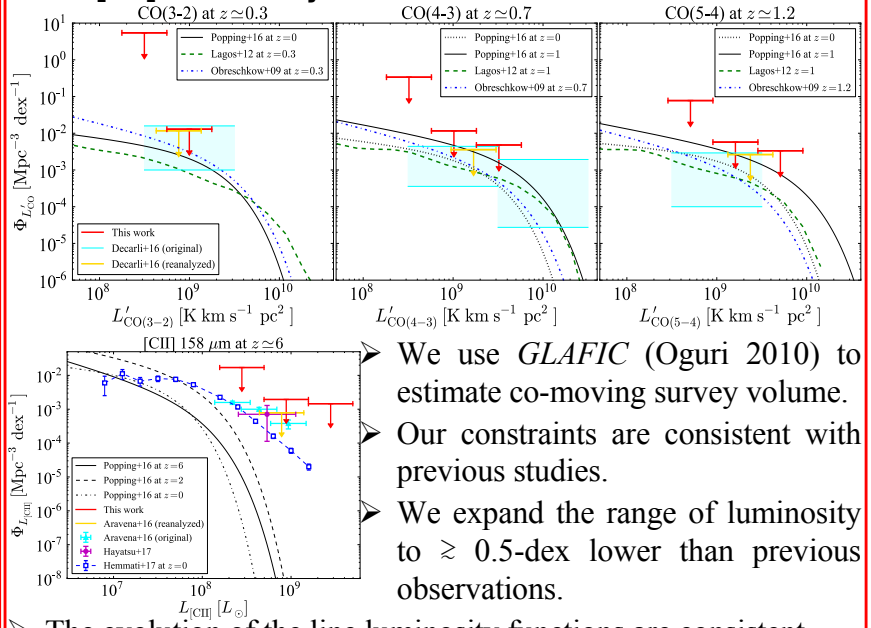


Results

We could not detect any line-emitters, but we found one line-emitter candidate with peak S/N = 4.5.



CO & [CII] luminosity functions



- We use *GLAFIC* (Oguri 2010) to estimate co-moving survey volume.
- Our constraints are consistent with previous studies.
- We expand the range of luminosity to ≳ 0.5-dex lower than previous observations.
- The evolution of the line luminosity functions are consistent with the predictions of semi-analytical models.
- Wide observations with a single frequency tuning toward lensing clusters are promising for constraining the line luminosity functions.

Reference: Decarli et al. 2016, ApJ, 833, 69; Lagos et al. 2012, MNRAS, 426, 2142; Obreschkow et al. 2009, ApJ, 698, 1467; Obreschkow et al. 2009, ApJ, 702, 1321; Oguri 2010, PASJ, 62, 1017; Popping et al. 2016, MNRAS, 461, 93; Walter et al. 2016, ApJ, 833, 67; Williams et al. 1994, ApJ, 428, 693